copper-colored light which lingered, for a large portion of a second, on the Moon's dark limb at the point of disappearance. After the last trace of the eastern end of the ring had disappeared, the limb was rendered visible for several seconds of arc each way from the point of disappearance. This phenomenon would seem to point to the existence of a low-lying lunar atmosphere, or of a faint luminous atmosphere round the planet itself.

THE OBSERVATORY,
WINDSOR, N. S. W., June 5, 1893.

CONSIDERATIONS ON THE METHODS OF REPRESENTING THE MILKY WAY, SUGGESTED BY A RECENT WORK.*

BY EDWARD S. HOLDEN.

Mr. EASTON's introduction tells us that his drawings of the Milky Way were made in the years 1882-87, and that in their definitive form they refer to the latter year. The work is an entirely independent one. It was not until 1892 that Mr. EASTON compared his designs with the maps of HEIS and BOEDDICKER. This comparison shows differences between the drawings of the three observers; but these differences are such as are usually found between the drawings of the same celestial object by different artists, and in Mr. EASTON'S opinion it is quite practicable to obtain a satisfactory agreement in such visual drawings if sufficient pains are taken. Where three observers agree we may assume that all three are right. Where they differ further work is necessary. There appears to be a sufficient discrepancy between certain parts of the drawings of Messrs. EASTON and BOEDDICKER to require some revision of the sort. The nature of the difficulties to be surmounted is familiar to those who have made such drawings, or it can be made plain to anyone who will examine a series of drawings of planets, the nebula of *Orion*, or of regions on the Moon, by different observers.

After the drawings were finished, Mr. EASTON had great diffi-

*C. EASTON: *La Voie Lactée dans l'hémisphère boréal.* (Containing five plates lithographed by the author, a detailed description, a catalogue of stars, etc., an historical notice together with a preface by Professor H. G. v. d. S. BAKHUYZEN, Director of the Observatory of Leyden.) Paris: Gauthier-Villars, 1893. Atlas folio.

culty in finding a suitable method of reproducing them. Methods of reproduction by photography were tried without success, and it was finally decided to lithograph the maps, the author himself making the drawings on the stone. Everyone who has had to do with the problem of producing a large edition of plates, which must be absolutely alike, from a single original (either drawing or photograph), will understand the difficulty. Even the lithographic impressions were not entirely similar, and Mr. EASTON touched up, by hand, the different plates as they came from the press. The atlas is, then, as nearly representative of the original drawings as it can well be made.

No doubt the process employed by Mr. EASTON (and first practiced, I believe, by Dr. LÖHSE in his drawings of Sun spots, in the Potsdam observations) is as nearly satisfactory for reproducing *drawings* as any other. If drawings are reproduced by photography, the very first copy on a sensitive plate changes all the contrasts of the original design. It is usual to send this first negative to the person who is to make the process-block for printing, and who must make another copy on a "stripping-plate," or on something equivalent. These stripping-plates are usually very slow and the contrasts are again much changed by the transfer. Finally, the block is made, and in the course of printing the impressions new changes of contrast come in, not to speak of great losses of definition. If the original is a negative, and not a drawing, difficulties of precisely the same sort are present. Definition is always lost and the contrasts are always changed, more or less. Our experience at the LICK Observatory has been considerable, and we have found reproductions by heliogravure (on copper) to be the most satisfactory. They are hardly more than twice as expensive as the best "processes," and they are very much superior.

Mr. EASTON'S remarks on the difficulties of representing the Milky Way by eye-drawings are of importance in themselves and they apply directly to all drawings of faint objects, as comets or nebulæ. Strictly speaking, no two observers see the same Milky Way. Nor do two different photographic telescopes, plates, foci, or exposure-times depict identically the same details. Since the application of photography to such delineations it has become a question whether it is worth while to spend the necessary time and pains upon *drawings* of such subjects as photography is fitted to deal with.

It is certain that a photograph, properly taken, will show many features of comets, nebulæ and the Milky Way which the eye cannot grasp as well, or even at all. Thus the "photographic" Milky Way must always be different from the "visual" one, and future researches may well be directed solely to the former. The recent photographs of Comet *Swift* (April, 1892), of Comet *b* (July, 1893) and of Comet *Brooks* (October, 1893) taken at the LICK Observatory, by Professors BARNARD and HUSSEY, exhibit several features in the fainter portions of these comets which are not visible to the eye and which have not been seen in earlier comets. Yet it is very possible, and even probable, that these features may have been present in former bright comets. For the tails of comets, then, we shall always prefer photographs to drawings. The case is entirely the same for nebulæ. Why should it be different for the Milky Way? Photographs of the Milky Way do, in fact, show some features which the eye cannot see at all (and hence duplicate negatives should be taken for verification) and they show very many others which the eye sees, indeed, but not with sufficient sharpness to allow of a satisfactory delineation. The photograph has, however, errors of its own which are of the same general nature as the errors of the human retina; and it takes account of one part of the spectrum only.*

A considerable part of the luminous background of the Milky Way, as seen with the naked eye, is due to the fact that the eye cannot separate the different stars which really exist in the sky and whose images, therefore, overlap on the retina. Moreover, the eye cannot be rigidly fixed on one area, but leaves it and returns to it continuously; and hence the persistence of vision contributes also to the formation of the luminous background which we (apparently) see. A considerable part of this background has, therefore, no real existence, but is a strictly subjective appearance, and must, consequently, be different to different eyes. When a telescope is employed to view the Milky Way, phenomena of the same general nature occur. A telescope has a greater separating power than the eye, and more stars are separately seen; but those which are not individually shown produce the effects just described. The larger the telescope the greater the separating power and the larger the number of stars which form their individual images, and the fewer stars, therefore,

* See *Publications* A. S. P., Vol. I, page 119.

whose images overlap and go to form a luminous background. The larger apertures will, therefore, give the greatest number of individual stars, the least amount of false background and the truest representation of the Milky Way as it veritably is.

Each different telescope, aperture and magnifying-power produces a different appearance. If, now, we employ a telescope to form a photographic image on a sensitive film (which film always has a sensible thickness), a luminous background will be produced, due to the causes named above and to others peculiar to photography. All the stars separated by the telescope will form definite images on the front surface of the film and will affect the particles of silver at that surface, producing photographic images. Some of the light which goes to form a given image will pass through the film and be reflected from the back surface of the glass plate, and returning through the film will produce *halation* rings around the central image. The light which thus passes through the film, twice, meets particles of silver in its course. It tends to decompose all the particles which it meets. Some of it is reflected from their surfaces also and irregularly dispersed, and many particles of silver which are not in the *direct* path of any ray are, nevertheless, affected by these irregularly scattered rays. All the stars which are too close together in the sky to be separated by the photographic telescope employed will form overlapping images on the film, and will thus contribute to form a luminous, nebulous background, which is, in part, simply an instrumental defect, and not a fact of nature. The imperfect polish of the lenses or mirrors of the photographic telescope employed contribute to the same thing. The intensity of this background varies with the exposure-time, the amount of incident light, the aperture and focus, the kind of plate employed, and with the nature of the development. If the plate is not accurately in focus the instrumental defects are exaggerated. It is impossible to get rid of all instrumental shortcomings, but the most important one can be avoided. The reflections from the back surface of the glass plate which carries the sensitive film can be destroyed by suitably backing the plate either by a permanent coating or by the ingenious backing which Professor SCHAEBERLE has described in these *Publications*, Vol. IV, page 272.

It is very desirable to have complete pictures of the Milky Way as seen with the naked eye (these we now possess); with

small photographic telescopes (these are now being made at the LICK Observatory and elsewhere); and by greater instruments (these will eventually be obtained in the course of making the International Photographic Charts, and also with the BRUCE telescope of the Harvard College Observatory).

The object of all work of this kind is to determine the true nature of the Milky Way. This requires a comparison of maps made by instruments of varying power, and on a uniform plan throughout. The varying transparency of the sky at different altitudes and on different nights cannot be eliminated, but every other condition should be made as constant as possible. There is nothing new in the foregoing principles, but they seem to form a proper commentary on Mr. EASTON'S remarks as to the difficulties encountered in the problem of depicting the Milky Way.

Just as in the photographic photometry of stars it is of advantage to establish photographic magnitudes without any attempt to make them agree with visual magnitudes so in this case we shall do well to investigate the "photographic" Milky Way without any reference to the "visual" one.

After taking into account all the advantages and disadvantages of the best possible representations of the Milky Way made by the eye and made by photography, it seems to be unquestionable that the latter process is the only one which should be employed in the future. The photographic representations if made according to a fixed programme are entirely satisfactory and have a definite meaning. Drawings may be of very high value—as for example the drawings of Messrs. BOEDDICKER and EASTON, but it seems to be certain that the time, patience, skill and artistic talent lavished on such drawings can, in the present state of science, be more usefully employed. The case is analogous to that of the Nebula of *Orion*. We have every reason to be grateful to the observers who have given us accurate drawings like those of LASSELL, BOND, ROSSE, but the magnificent photograph of Mr. COMMON has a higher authority than everything that preceded it. In the same way suitable photographs of the Milky Way will, I think, take the place of even the best drawings of it, such as the maps of Mr. EASTON.

There is an important economy possible in photography which is obvious enough but which should not pass without mention. If a pair of exactly similar cameras are mounted side by side, it

is practicable to obtain *duplicate* plates for the final chart with a *single* exposure. Other cameras giving larger (or smaller) areas can readily be exposed at the same time. A *cluster* of cameras can be pointed about as readily as a pair, and five or six plates can be obtained with a single exposure. Each camera and each plate will record a different galaxy (just as each eye sees its own Milky Way) but the very differences due to variations in light, focus, definition, plate, etc., are precisely what are needed to give the data for a thorough study, provided they are *simultaneously* recorded on the different plates.

The remarks made by Mr. EASTON upon the various theories of the Milky Way which have been enunciated are conceived in the true scientific spirit. It is certain that the galaxy presents streams and aggregations of stars which most strongly suggest definite laws of formation. It is entirely proper to point out the laws which are suggested. But it is of the first importance to insist that these results are, for the present, only suggestions. It seems to be quite possible that in the future the real laws in question may be discovered. The work of the present is, first and most important, to obtain the necessary data; and second, to discuss these data as completely as possible, but always with the explicit statement that, for the present, the data are insufficient.

Previous researches on the Milky Way from the time of PTOLEMY until the present day are described by Mr. EASTON in a succinct but valuable historical note. The description of PTOLEMY is given in full, with explanatory notes, in Appendix I. Appendix II is devoted to a description of the galaxy by Dr. KLEIN. Appendix III is a reprint of HOUZEAU'S determination of the brilliancy of various regions, with comparisons between these determinations and those of Mr. EASTON. A detailed description of the Milky Way (comprising 20 folio pages) is next presented by the author from his own observations, which is followed by a catalogue referring to the principal features—bright areas, streams, and dark spaces. Finally the atlas contains three detailed charts of the Milky Way, a general chart on a smaller scale, and an analytical map, in which the outlines of the various streams, etc., are laid down, but no shading given.

In concluding this brief notice, it is only just to point out that this work of Mr. EASTON'S appears to be a model of what such a work should be, and to say that it is very fortunate for science that we now have two such monographs of the Milky Way as those of BOEDDICKER and EASTON.

It seems to be also entirely proper to emphasize my personal opinion as to future researches of the kind, which is, that such future researches should be carried on by photography; and this for two reasons—*first*, the labor of skilled and faithful workers will thus be available for other investigations, *second*, the "photographic" Milky Way, as we may call it, can be mapped again and again during the time required to make a single complete drawing. It must be recollected, however, that both the drawings last mentioned were commenced and well under way before it was known how simply and satisfactorily such representations could be made by the camera.

LICK OBSERVATORY, December, 1893.

THE DISINTEGRATION OF COMETS.

BY PROFESSOR H. A. NEWTON.

[Professor H. A. NEWTON of Yale University recently delivered the following extempore address before the American Philosophical Society. It is of special interest, since no one is better qualified than Professor NEWTON to speak upon questions relating to meteors and comets.]

"I have to apologize somewhat in that I came to the rooms not expecting to speak to you. I have, however, one point which I think will interest the members of this Society if they will give me a few minutes to develop it, and that is, the force which acts on the small bodies sent off from comets and which form our shooting stars.

"There are in the comets so many questions that we cannot answer, so many curious and wonderful phenomena that are unexplained, that I am sure you will accept any explanation of any of them that seems plausible, as a matter of interest. From a comet there is continually driven off matter forming the tail, a light substance, and astronomers are agreed that the force that acts on the matter which forms the tail is a repulsive force from the Sun acting inversely as the square of the distance, the force of the repulsion being greater than that of attraction.

"Not only is this true, but different parts of that tail are acted upon by repulsive forces of different powers; otherwise the tail